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Anthropogenic Concentrations of Cd, Ni and Zn in the Intertidal, River and Drainage Sediments Collected from North Western Peninsular Malaysia

Yap, C. K.* **and Pang, B. H.**

Department of Biology, Faculty of Science,
Universiti Putra Malaysia, 43400 UPM, Serdang,
Selangor, Malaysia
**E-mail: yapckong@hotmail.com*

ABSTRACT

Surface sediments were collected from the north western intertidal area (14 sites), drainage (3 sites), and rivers (3 sites) of Peninsular Malaysia in April 2005. The samples were analyzed for their concentrations of Cd, Ni, and Zn. The ranges for the total concentrations (µg/g dry weight) of Cd, Ni, and Zn were found to be 0.79-2.48, 6.46-73.92, and 33.6-484.14, respectively. Factory drainage site at Juru exceeded the established sediment quality values (Effect Range Median-ERM) for Zn and Ni, while the concentrations of Zn were also found to have exceeded the ERM at drainages at Kuala Kurau Town and Sg. Juru sites. The geochemical study, based on the sequential extraction technique on the sediments, revealed that the metal percentages of non-resistant fractions of the drainage at Kuala Kurau Town (drainage), Sg. Juru (river), Kuala Juru (intertidal), and factory drainage site at Juru were higher than the resistant fractions of the metals. These indicated that the sites (intertidal, river, and drainages) received anthropogenic inputs of these metals. Therefore, the point source of anthropogenic input in these sites should be given attention in future in order to mitigate the environmental problem on the living resources in the north western of Peninsular Malaysia. The present monitoring data are useful for future establishment of sediment quality guideline for Malaysian aquatic environment.

Keywords: Cd, Ni and Zn, north western Peninsular Malaysia

INTRODUCTION

Literatures on heavy metal concentrations in the surface sediments of the west coast of Peninsular Malaysia have been reported based on the samples collected between 1999-2004 (Yap *et al.*, 2002: 2003: 2005: 2006). Besides, the east coast sediments of Peninsular Malaysia have also been documented (Shazili *et al.*, 1987:1989; Shazili and Mawi, 1988; Yap *et al.*, 2008a). All of these monitoring studies imply the importance of such data from the environmental management point of view. In order to establish the local sediment quality guidelines of metals for this area, monitoring the data throughout a timeframe is therefore necessary. The findings of the present study are aimed to serve as a part of the monitoring work towards achieving the Malaysian sediment quality guidelines for heavy metals in future.

Reviewing the published work of heavy metal concentrations in sediment from Peninsular Malaysia by Yap *et al.* (2002) and Yap *et al.* (2003) is interesting; nonetheless, a question this crops up from it is, “What are the metal levels after 5 years at the same sampling sites based on the sediment samples?” Yap *et al.* (2002: 2003) reported the metal data based on the sediments collected in 1999-2001. It is therefore interesting to know the metal levels in the sediments collected from the west coast of Peninsular Malaysia in 2005.

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*Corresponding Author

In this paper, surface sediments were collected in April 2005, using the method described by Yap *et al.* (2002, 2003). The advantages of using sediment as an indicator of heavy metal pollution is well-known in the literature (Yap *et al*., 2002: 2003a, b, c: 2005: 2006). The significance of this work is to compare the levels of Cd and Zn with those reported by Yap *et al.* (2003) and to set continued monitoring data for future references. Therefore, the objective of this study was to determine the concentrations of Cd, Ni, and Zn in the sediment from the north western part of Peninsular Malaysia collected in April 2005. Besides, this study was also done to determine the Cd, Ni, and Zn pollution based on the geochemical distribution (non-resistant and resistant fractions) of these metals in the sediments that were collected from the north western part of Peninsular Malaysia. The three geochemical fractions (easily, freely, leachable or exchangeable or EFLE, acid-reducible and oxidisable-organic), based on the sequential extraction technique, are useful in identifying the polluted sites in Malaysia (Yap *et al.*, 2007b). The data of this study were compared with those reported in the studies carried out in this region and Malaysia, as well as the established sediment quality values proposed by Long *et al.* (1995).

MATERIALS AND METHODS

The samples of sediment were collected on 18-20 April 2005 from 20 sampling sites that are located in the north western intertidal area (17 sites) and drainage (3 sites) of Peninsular Malaysia (see *Fig. 1*). The positions, sampling dates and site descriptions are given in Table 1. The top 3-5 cm of the surface sediments were collected at each sampling site. Each sediment sample was put in a plastic bag and frozen prior to analysis. The parameters of the surface water (0-20cm) samples recorded directly in the field at each sampling station were temperature, pH, specific conductivity (SpC), total dissolved solid (TDS), as well as salinity and dissolved oxygen (DO) using a Hydrolab Datasonae 4a water quality multi-probe.

The sediment samples were dried using an oven at 60°C until constant dry weights. Later, the dried sediments were pounded using a clean pestle and mortal and they were also sieved through a 63 μm stainless steel aperture. While sifting, the sieve was shaken vigorously to produce homogeneity (Yap *et al.*, 2002a) before they were stored in clean and new plastic bags.

In this study, the direct aqua-regia method was used to determine the concentrations of Cd, Ni, and Zn in the dried sediment samples. Firstly, about 1 g of each dried sample was weighed and digested in a combination of concentrated nitric acid (HNO3, AnalaR grade, BDH 69%) and perchloric acid (HClO4, AnalaR grade, BDH 60%) in the ratio of 4:1. After that, the tubes were put into the digestion block at the low temperature (40°C) for 1 hour and the temperature was then increased to 140°C for at least 3 hours. The digested samples were diluted to 40 ml in double distilled water and filtered through Whatman No.1 (filter speed: medium) filter paper in a funnel into acid washed pillboxes. After that, they were stored until metal determination.

The geochemical fractions of Cd, Ni, and Zn in the sediment were obtained using the Sequential Extraction Technique (SET), as described by Badri and Aston (1983) and modified by Yap *et al.* (2002). They are four fractions considered in this method, namely ‘easily, freely, leachable or exchangeable’ (EFLE), acid-reducible, oxidisable-organic, and resistant fractions.

Prior to the next fractionation, the residue for each fraction was weighed. The residue was then rinsed using 20 ml of double distilled water. After that, it was filtered through a Whatman No.1 (Filter speed: medium) filter paper in a funnel and the filtrates were stored for the next step. For each fraction of the sequential extraction procedure, a blank was employed using the same procedure to ensure that the samples and chemicals used were free of contamination.

After the filtration, the sample was determined using an air-acetylene flame Atomic Absorption Spectrophotometer (AAS), an inorganic analytical instrument made by Perkin-Elmer Model AAnalyst 800. All the data are presented in μg/g dry weight basis.

TABLE 1
Positions, sampling dates and description of the sampling sites for the intertidal sediment collected from the north western part of Peninsular Malaysia

St	Location	Sampling date	Latitude	Longitude	Description
1	Kampung Kuantan, Selangor	18 April 2005	101º18.093’ E	03º21.745’ N	River; A riverside, recreational park
2	Kampung Penambang, Selangor	18 April 2005	101º18.096’ E	03º21.744’ N	Intertidal; A small jetty, the fishing village
3	Sungai (Sg.) Bernam, Selangor	18 April 2005	101º14.965’ E	03º21.599’ N	River; Under a bridge of a main highway
4	Hutan Melintang, Perak	18 April 2005	100º55.965’ E	03º52.345’ N	Intertidal; A fishing village
5	Pelabuhan Hutan Melintang, Perak	18 April 2005	101º14.965’ E	03º21.599’ N	Intertidal; An abundant port, fishing village in the other side
6	Bagan Datoh, Perak	18 April 2005	100º47.150’ E	03º59.563’ N	Intertidal; A fishing village
7	Jambatan Raja Permaisuri Bainon (JRPB), Perak	18 April 2005	100º39.335’ E	04º16.803’ N	Intertidal; Under an overhead bridge
8	Kuala Kurau (jetty), Perak	19 April 2005	100º25.867’ E	05º00.928’ N	Intertidal; A jetty
9	Kuala Kurau (town), Perak	19 April 2005	100º26.017’ E	05º01.052’ N	Drainage; A small town, many kind of shops
10	Batu 14 Jalan Pantai, Kurau, Perak	19 April 2005	100º24.779’ E	05º01.106’ N	Drainage; A highway side
11	Bagan Tiang (offshore), Perak	19 April 2005	100º22.459’ E	05º08.517’ N	Intertidal; An offshore, fishes and mussel aquacultura
12	Bagan Tiang (jetty), Perak	19 April 2005	100º23.840’ E	05º06.702’ N	Intertidal; A jetty and fishing village
13	Sungai (Sg.) Berembang, Kedah	19 April 2005	100º08.787’ E	06º21.313’ N	Intertidal; A rocky shore
14	Kuala Perlis, Perlis	19 April 2005	100º07.740’ E	06º23.927’ N	Intertidal; A jetty
15	Alor Setar, Kedah	20 April 2005	100º21.595’ E	06º07.420’ N	Drainage; An urban area, many kind of shops and vehicles
16	Kuala Kedah, Kedah	20 April 2005	100º17.149’ E	06º06.333’ N	Intertidal; A jetty and fishing village
17	Kampung Kuala Muda, Kedah	20 April 2005	100º21.735’ E	05º34.343’ N	Intertidal; A jetty and fishing village
18	Sungai (Sg.) Juru, Penang	20 April 2005	100º26.083’ E	05º19.772’ N	River; roadside near the industrial site
19	Jetty Kuala Juru, Penang	20 April 2005	100º24.518’ E	05º20.410’ N	Intertidal; A fishing village and a jetty
20	A drainage near factory site at Juru, Penang	20 April 2005	100º26.011’ E	05º20.105’ N	Drainage; An industrial area

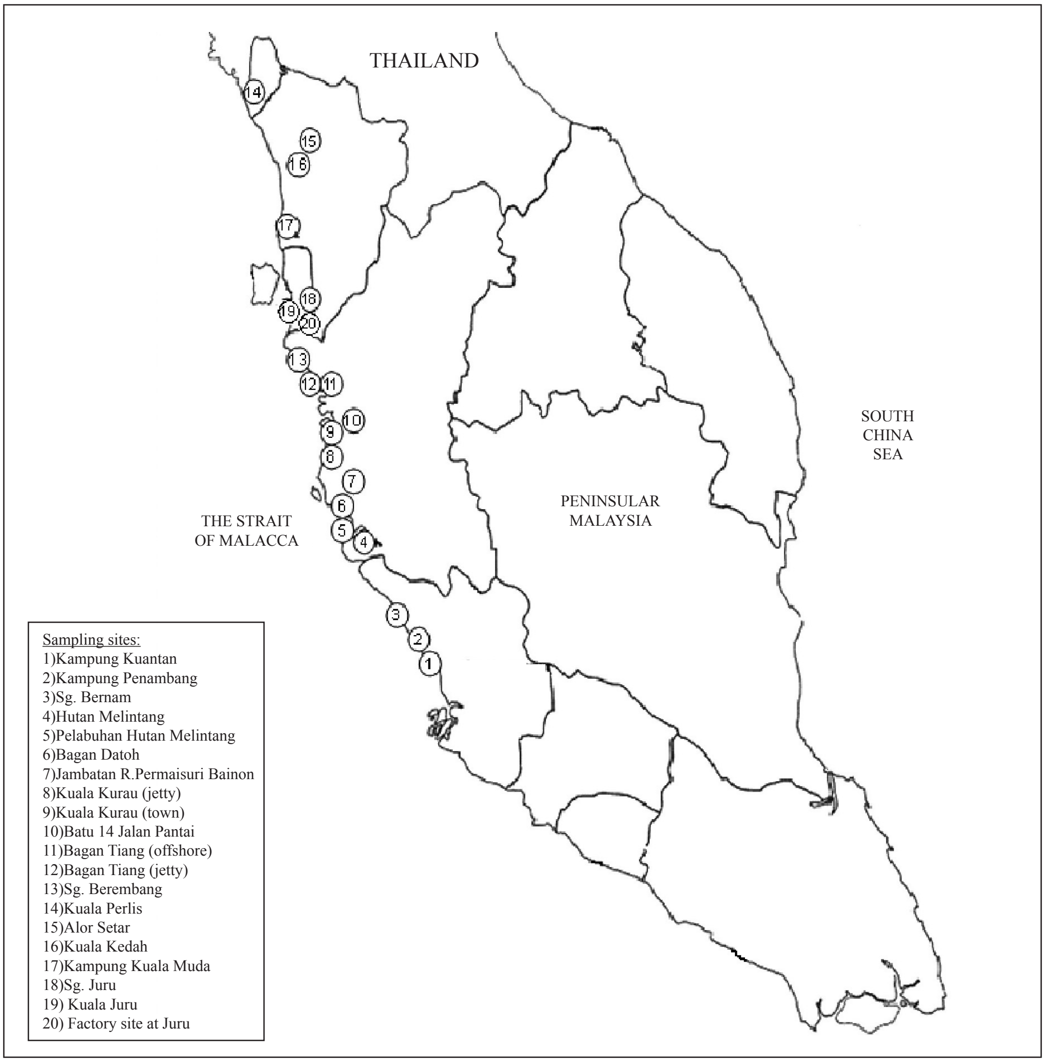

Fig. 1: Sampling locations of the surface sediments in the north western coast of Peninsular Malaysia

The quality of the method used was checked using the Certified Reference Material (CRM) for Soil (International Atomic Energy Agency, Soil-5, Vienna, Austria). The agreement between the analytical results for the reference material and its certified values for each metal were found to be satisfactory with the percentages of recovery ranging between 144% for Cd, 124.6% for Ni and 87% for Zn (Table 2). Meanwhile, the procedural blanks and quality of the control samples, made from the standard solutions for Cd, Ni, and Zn prepared from 1000 mg/L stock solution (MERCK Titrisol) of each metal, were analyzed for every five to ten samples to check for the sample accuracy.

TABLE 2
A comparison of the measured and certified concentrations (µg/g dry weight) of Cd, Ni, and Zn f
or the Certified Reference Material for soil

Metal	Certified value (C)	Measured value (M)	Percentage of recovery (M/C)
Cd	1.5	2.16	144.0
Ni	1.3	1.62	124.6
Zn	368	323.24	87.8

TABLE 3
Some surface water parameters recorded *in-situ* during the sampling for all the 20 sampling sites

No.	Sampling sites	Temp (ºC)	SpC (µS/cm)	TDS (mg/L)	Salinity (ppt)	DO (mg/L)	pH
1	Kampung Kuantan	29.26	87	0.52	0.04	2.17	7.63
2	Kampung Penambang	30.18	12366	7.27	6.33	5.87	8.73
3	Sungai Bernam	31.27	765	0.44	0.33	3.09	7.62
4	Hutan Melintang	33.15	12504	7.03	6.06	4.65	8.66
5	Pelabuhan Hutan Melintang	34.30	17423	9.62	8.48	7.26	9.53
6	Bagan Datoh	33.71	10529	5.87	4.98	7.14	9.30
7	JRPB	33.02	52039	29.3	28.96	NA	10.29
8	Kuala Kurau (Jetty)	31.44	25081	14.5	13.34	3.92	8.94
9	Kuala Kurau (Town)	29.47	476.330	0.29	0.21	0.75	8.70
10	Batu 14 Jalan Pantai	29.53	380	0.23	0.16	0.79	8.40
11	Bagan Tiang (Offshore)	32.18	47416	27.1	26.51	9.03	10.13
12	Bagan Tiang (Jetty)	32.14	7971	4.559	3.81	2.49	8.51
13	Sungai Berembang	32.36	54219	30.9	30.71	6.76	9.82
14	Kuala Perlis	31.43	49657	28.9	28.53	5.58	9.70
15	Bandar Alor Setar	30.04	141	0.08	0.06	0.48	8.31
16	Jetty Kuala Kedah	30.29	1853	1.09	NA	4.60	8.81
17	Kuala Muda	33.40	33576	18.8	17.68	7.62	9.80
18	Sungai Juru	35.28	87	0.05	0.04	2.17	7.63
19	Kuala Juru	33.02	40324	40324	21.80	8.59	9.27
20	Factory site at Juru	32.11	1436	0.82	0.62	0.42	8.54

Note: Temp = temperature; SpC = specific conductivity; TDS = total dissolved solid; DO = dissolved oxygen

RESULTS AND DISCUSSION

The temperature, pH, SpC, TDS, salinity and DO recorded *in-situ* on the water surface from 20 sampling sites are given in Table 3. The range of these parameters are 29.26-35.28ºC for temperature, 87-54219 µS/cm for SpC, 0.05-40324 mg/L for TDS, 0.04-30.71 ppt for salinity, 0.42-9.03 mg/L for DO and 7.62-10.29 for pH. From the salinity data, it is clear that Kg. Kuantan (0.04 ppt), Sg. Bernam (0.33 ppt), and Sg. Juru (0.04 ppt) are the rivers with little influence from the marine seawater, while Kuala Kurau Town (0.21 ppt), Batu 14 Jalan Pantai at Kurau (0.16 ppt), Bandar Alor

TABLE 4
Total concentrations (µg/g dry weight ± standard error) Cd, Zn and Ni in the surface sediments collected from 20 sampling sites, based on the aqua-regia method

No.	Sampling site	Cd			Zn			Ni		
1	Kampung Kuantan	1.74	±	0.19	119.72	±	2.09	28.01	±	0.05
2	Kampung Penambang	1.46	±	0.03	54.68	±	0.38	25.86	±	0.30
3	Sungai Bernam	2.23	±	0.08	101.32	±	0.46	36.33	±	0.45
4	Hutan Melintang	1.63	±	0.20	83.80	±	2.14	34.33	±	0.26
5	Pelabuhan Hutan Melintang	1.69	±	0.07	71.15	±	0.90	33.78	±	0.51
6	Bagan Datoh	2.09	±	0.08	87.99	±	0.53	31.76	±	0.35
7	J.Raja Permaisuri Bainon	1.63	±	0.14	38.95	±	0.33	6.46	±	0.41
8	Kuala Kurau (Jetty)	1.70	±	0.10	74.64	±	1.05	21.82	±	0.25
9	Kuala Kurau(Town)	2.48	±	0.09	429.46	±	1.19	47.90	±	0.67
10	Batu 14 Jalan Pantai	1.69	±	0.05	88.74	±	2.06	14.21	±	0.43
11	Bagan Tiang (Offshore)	2.24	±	0.17	106.04	±	3.81	27.72	±	0.48
12	Bagan Tiang (Jetty)	1.60	±	0.09	73.22	±	3.42	25.40	±	0.30
13	Sungai Berembang	1.38	±	0.22	57.32	±	0.80	23.50	±	1.22
14	Kuala Perlis	1.42	±	0.11	55.73	±	1.32	25.02	±	0.45
15	Bandar Alor Setar	1.47	±	0.25	187.21	±	1.84	24.23	±	0.26
16	Jetty Kuala Kedah	1.09	±	0.17	53.21	±	0.73	25.75	±	0.29
17	Kuala Muda	0.79	±	0.08	33.60	±	1.01	21.08	±	0.44
18	Sungai Juru	1.40	±	0.19	461.33	±	1.86	46.61	±	0.71
19	Kuala Juru	1.24	±	0.10	317.39	±	2.48	50.28	±	0.75
20	Factory site at Juru	1.46	±	0.20	484.14	±	3.01	**73.92**	±	0.28

Setar (0.06 ppt) and the factory site in Juru (0.62 ppt) are concrete drainages potentially receiving effluents from industrial discharges or domestic wastes. Although these water parameters are difficult to explain the present metal data on the surface sediments, these aquatic parameters can, at least, indicate whether or the influence of marine seawater is significant.

The total concentrations of Cd, Ni, and Zn based on aqua-regia method for all the sampling sites are shown in Table 4, while the overall mean metal concentrations for each fraction with their total concentrations are presented in Table 5. The ranges for the total concentrations of Cd, Ni, and Zn were 0.79-2.48 µg/g dw, 6.46-73.92 µg/g dw, and 33.6-484.14 µg/g dw, respectively. In particular, the Kuala Kurau Town drainage was found to have the highest concentrations of Cd (2.48 µg/g dw), while the lowest concentration of Cd was recorded at Kuala Muda (0.79 µg/g dw). As for Zn and Ni, the highest concentration was recorded at a drainage site at the factory site at Juru Industrial area, while the lowest levels for both metals were found at Jambatan Raja Permaisuri Bainon (JRPB).

Meanwhile, the total concentrations of Cd, Ni, and Zn in the sediments collected from the north western part of Peninsular Malaysia were compared with those reported from Malaysia, as shown in Table 6. For Cd, four sites were shown to have recorded higher Cd levels [St-3 (2.23 µg/g dw), St-6 (2.09 µg/g dw), St-9 (2.48 µg/g dw), and St-11 (2.24 µg/g dw)] than the reported data in the intertidal and offshore of Peninsular Malaysia (Yap *et al.*, 2003), but significantly lower than the Cd concentrations at the Serdang industrial drainage sediments (Cd: 10.6-15.9 µg/g dw) (Yap *et*

TABLE 5
The overall mean concentrations (µg/g dw) of Cd, Zn, and Ni in the different geochemical fractions and their total concentrations in the surface sediments collected from the northern part of Peninsular Malaysia (based on 20 sampling sites)

Metal	Fraction	Min - Max	Mean ± SE
Cd	Total	0.79-2.48	1.622 ± 0.090
	Summation	0.95-4.68	2.712 ± 0.265
	F1	0.03-0.43	0.162 ± 0.025
	F2	0.04-0.38	0.187 ± 0.024
	F3	0.03-0.69	0.405 ± 0.044
	F 4	0.54-3.91	1.958 ± 0.242
Zn	Total	33.6-484.14	148.98 ± 32.962
	Summation	50.06-619.95	165.51 ± 32.567
	F1	0.37-59.37	11.447 ± 4.468
	F2	1.92-63.35	21.765 ± 5.165
	F3	11.75-86.58	39.366 ± 6.120
	F 4	17.54-413	92.932 ± 19.518
Ni	Total	6.46-73.92	31.199 ± 3.285
	Summation	10.12-75.36	29.157 ± 3.699
	F1	0.007-1.67	0.607 ± 0.113
	F2	0.007-3.3	0.926 ± 0.207
	F3	2.73-42.35	11.915 ± 2.308
	F 4	5.36-29.01	15.709 ± 1.338

Note: F1 = easily, freely, leacheable or exchangeable (EFLE), F2 = acid-reducible, F3 = oxidisable-organic and F4 = resistant

al., 2006a: 2008c) and within the Cd ranges of 6 intertidal areas in Selangor (Yap *et al.*, 2008c) and Kelana Jaya urban lakes (Ismail *et al.*, 2004) (*see* Table 6).

The range of Ni obtained from this study (6-74 µg/g dw) was comparable to that of the Kelana Jaya urban lakes (0.48-2.68 µg/g dw) (Ismail *et al.*, 2004), although wider to the Ni concentrations found in the Strait of Johore at 21.2-46.8 µg/g dw (Wood *et al.*, 1997); however, it was lower than the drainages near the industrial area in Peninsular Malaysia (121 µg/g dw) (Yap *et al.*, 2007b: 2008b). Other comparisons are also shown in Table 6.

In the study, four sites were found to have recorded higher levels of Zn than the previously reported data in Malaysia (Table 6); these were Kuala Kurau Town (429.46 µg/g dw), Sg. Juru (461.33 µg/g dw), Kuala Juru (317.4 µg/g dw) and a factory site at Juru (484.14 µg/g dw). Apparently, the three sites exceeding 400 µg/g were also comparable to most polluted drainages including the sites near a petrochemical plant, an electronic factory, a metal factory and two townships (Yap *et al.*, 2007a) and Kelana Jaya urban lakes (Ismail *et al.*, 2004) in Peninsular Malaysia (Table 6). The present Zn ranges were also found to be much higher than the Zn concentration (22.3 µg/g dry weight) found in the surface sediment of Kerteh Mangrove Forest in Terengganu (Yunus and Ong, 2008). In general, the concentrations of Cd and Zn found in the intertidal, river, and drainage sediments from the present study were also much higher than those reported in the east coast of Peninsular Malaysia, as reviewed by Shazili *et al.* (2006).

TABLE 6
Comparison of Cd, Zn, and Ni (μg/g dry weight) of the surface sediment data reported from Malaysia and this region

No.	Location	Cd	Zn	Ni	Reference
	Malaysian studies				
1.	Coast of Penang, Malaysia	BDL-6.8	73-109	NA	Seng *et al.* (1987)
2.	South China Sea	0.41-2.39	12-50	NA	Shazili *et al.* (1987)
3.	Offshore Sarawak	BDL-0.01	25-112	NA	Shazili and Mawi (1988)
4.	Offshore Terengganu, Pahang, Sarawak and Sabah	BDL-5.6	5-107	NA	Shazili *et al.* (1989)
5.	Langat River, Malaysia	3.0-37.9	71-374	NA	Sarmani (1989)
6.	Port Kelang, Malaysia	< 6.0	11-66	NA	Ismail *et al.* (1989)
7.	Bintulu coastal waters, Malaysia	1-5	39-91	NA	Ismail (1993)
8.	West of Peninsular Malaysia	<10.0	50-1400	NA	Ismail *et al.* (1993)
9.	Straits of Johore	1.70	26.1	5.4	Mat *et al.* (1994)
10.	Juru River, Malaysia	-	29-316	NA	Lim and Kiu (1995)
11.	Sarawak River, East Malaysia	-	8-48.4	NA	Lau *et al.* (1996)
12.	Johore Straits	0.11-0.36	68-231	21-47	Wood *et al.* (1997)
13.	Sepang Besar River, Malaysia	0.1-2.1	4-550	NA	Ismail and Ramli (1997)
14.	South China Sea Off Peninsular Malaysia and Borneo	0.1-0.91	18-98	NA	Shazili *et al.* (1997)
15.	Seberang Prai, Penang	0.27-4.68	30-513	NA	Ismail and Asmah. (1999)
16.	Intertidal area of the west coast of Peninsular Malaysia	0.03-1.98	3-306	NA	Yap *et al.* (2003)
17.	Kelana Jaya Lakes, Selangor	0.48-2.68	107-529	NA	Ismail *et al.* (2004)
18.	Sri Serdang Industrial Area	2.40-10.2	169-296	35-582	Yap *et al.* (2006a)
19.	Tg. Piai, Malaysia	0.72–1.19	40–43	10-11	Yap *et al.* (2006b)
20.	Sepang River, Selangor	NA	34-421	NA	Yap *et al.* (2007a)
21.	Drainage sediments from Peninsular Malaysia (6 sites)	1.46-15.9	330-484	47.0-121	Yap *et al.* (2007b)
22.	East coast of Peninsular Malaysia (10 sites)	NA	55-86	NA	Yap *et al*. (2008a)
23.	South coast of Peninsular Malaysia (5 sites)	NA	38.1-221	NA	Yap *et al.* (2008a)
24.	West coast of Peninsular Malaysia (5 sites)	NA	36-395	NA	Yap *et al.* (2008a)
25.	Intertidals and drainages, Selangor	NA	50-336	15-121	Yap *et al.* (2008b)
26.	Sri Serdang Industrial Area, Selangor	15.9	NA	NA	Yap *et al.* (2008c)
27.	Six intertidal area and 4 urban drainage sites, Selangor	1.39-3.41	NA	NA	Yap *et al.* (2008c)
28.	Kerteh Mangrove Forest in Terengganu	NA	22.3	NA	Yunus and Ong (2008)
29.	Sri Serdang Industrial Area, Selangor (1 site)	NA	219	NA	Yap *et al.* (2009)
30.	Northern part of Peninsular Malaysia	0.79-2.48	33-484	6-74	This study

Table 6: Continued

	Regional Studies				
1.	Pearl River Delta, China	1.2-3.9	46.4-533.3	6.3-71	Cheung *et al.* (2003)
2.	Coastal Alang–Sosiya, India	8.57–45.9	718.02–1,483	60–222	Reddy *et al.* (2004)
3.	Semarang, Indonesia	NA	84-259	17-36	Takarina *et al.* (2004)
4.	Mangrove area, Singapore	0.18–0.27	51–120	7.44–11.7	Cuong *et al*. (2005)
5.	Kranji and Pulau Tekong, Singapore	0.06–0.19	49–62	17–26	Cuong and Obbard (2006)
6.	Gaunabara Bay, Brazil	NA	5–755	1–3,516	Baptista-Nito *et al.* (2006)
7.	Mandovy estuary, India	NA	19.9–86	NA	Alagarsamy (2006)
8.	Western Xiamen Bay, China	0.33	139	37.4	Zhang *et al.* (2007)
9.	Kaoshiung Harbor, Taiwan	0.1–6.8	52–1,369	NA	Chen *et al.* (2007)
10.	Pearl River Estuary, China	1.84-6.43	120-478	13-318	Li *et al.* (2007)
11.	Victoria Harbour, Hong Kong	NA	52-221	NA	Chloe *et al.* (2008)
12.	Dumai coastal sediment, Indonesia (23 sites)	NA	32-88	NA	Bintal *et al.* (2008)
13.	Yantze River (intertidal zone), China	0.12–0.75	47-154	17-48	Zhang *et al.* (2009)
14.	Dumai coasts Indonesia (23 site)	0.46–1.89	31–87	7–19.9	Bintal *et al.* (2009)

Based on the cluster analysis in *Fig. 2*, it can be summarized that St-9, St-18, St-19, and St-20 (the four sites mentioned above) are grouped into the same sub-cluster, indicating that these four sites have received more contamination of Cd, Ni, and Zn, due to their higher concentrations as shown in Table 4. Among the four sites, St-18, St-19 and St-20 are located in Juru area, which was previously reported to have been polluted by heavy metals (Lim and Kiu, 1995; Yap *et al*., 2002). Therefore, the present data also confirm continued point source of industrial discharge into the Juru basin area.

The data obtained in the present study are comparable or within the range of most regional studies summarized in Table 6. The present Cd ranges are lower than those of the Coastal Alang–Sosiya (India), Kaoshiung Harbor (Taiwan) and Pearl River Estuary (China), as well as comparable to other areas. The present Zn ranges were also found to be lower than the most polluted sites from the Coastal Alang–Sosiya (India), Gaunabara Bay (Brazil) and Kaoshiung Harbor (Taiwan) and were comparable to the river in other countries, such as the Pearl River Estuary in China. As for Ni, once again, the present Ni ranges were shown to be lower than the coastal Alang–Sosiya (India), Gaunabara Bay (Brazil) and Pearl River Estuary (China), and within the ranges of those from the other areas. However, it should be noted that the elevated concentrations of metals found in the present ranges were mostly recorded at St-9, St-18, St-19 and St-20, while the metal ranges of the other sites were in fact very much comparable to other coastal areas in this region, including the recently reported from Dumai (Indonesia) (Bintal *et al.*, 2008: 2009).

Although comparisons with other reported data may give a picture of the overall contamination level in Malaysia, the environmental consequences of these metals remain uncertain. Therefore, in order to estimate possible environmental consequences of Cd, Zn, and Ni at the studied sites, the metals were compared to the Sediment Quality Guidelines of Effect Range Low (ERL) and

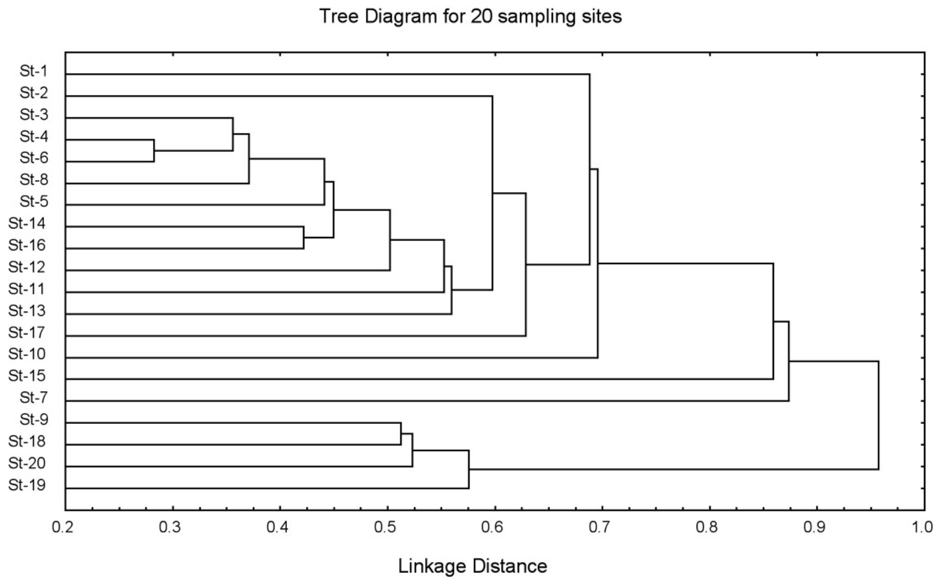

Fig. 2: Cluster analysis based on the Single Linkage Euclidean distances, on the Cd, Ni, and Zn concentrations in the sediments collected from 20 sampling sites, based on log_{10}(mean + 1) transformed data. All the sampling site numbers follow the names of the sampling sites in Table 1

Effect Range Median (ERM) proposed by Long *et al.* (1995). The findings of the present study showed that the Cd concentrations in most of the sites were between the values for ERL (1.2 µg/g) and ERM (9.6 µg/g). However, the Cd concentrations in all the sites were above the background concentration of non-contaminated sediment (0.17 µg/g), as suggested by Salomons and Forstner (1984). When compared to the Cd Sediment Quality Values (SQV) for Hong Kong (Chapman *et al.*, 1999), the present Cd ranges fell between SQV-low (1.5 µg/g) and SQV-high (9.6 µg/g), indicating a 'moderately polluted' status.

Meanwhile, the Zn concentrations in all the sites were still well below the values for the ERL (150 µg/g), except for Bandar Alor Setar and Kuala Juru (exceeding ERL value) and Kuala Kurau Town, Sg. Juru and the factory site in Juru (exceeding ERM: 410 µg/g). Similarly, all the sites were reported to be well below the SQV-low (200 µg/g) for Zn when compared to SQV for Zn (Chapman *et al.*, 1999), except for Kuala Juru which exceeded SQV-low, while Kuala Kurau Town, Sg. Juru and the factory site in Juru were found to have exceeded the SQV-high (410 µg/g), suggesting a 'highly polluted' status for the three sites.

For the concentrations of Ni, only two sites were found to be below the ERL value (20.9 µg/g), while the other sites exceeded the ERL value and the factory site in Juru exceeded the ERM value (51.6 µg/g). All the sampling sites, except for the factory site at Juru, were even still below the background concentration of non-contaminated sediment (52 µg/g for Ni), as suggested by Salomons and Forstner (1984). When compared to Ni SQV (Chapman *et al.*, 1999), all the present Ni ranges were found to exceed the SQV-low for Ni (40 µg/g for Ni), indicating a 'moderately polluted' status. However, the SQV-high for Ni has not been established.

Table 7 shows the percentages (%) of the four geochemical fractions of Cd, Zn, and Ni in the sediments collected from the northern part of Peninsular Malaysia. It is difficult to decide on the metal with the highest percentage of non-resistant fractions, but this is highly dependent on the sampling sites. In particular, cadmium was partitioned at 0.58-14.63% in the EFLE fraction,

TABLE 7

The percentages (%) of four geochemical fractions of Cd, Zn and Ni in the sediments

	CdF1	CdF2	CdF3	CdF4	NRCd	ZnF1	ZnF2	ZnF3	ZnF4	NRZn	NiF1	NiF2	NiF3	NiF4	NRNi
St-1	10.41	13.92	11.50	64.16	35.83	0.66	21.80	30.86	46.67	53.32	2.03	2.42	**22.75**	72.80	27.20
St-2	13.87	23.15	19.52	43.47	56.54	0.95	10.85	21.37	66.82	33.17	3.02	3.26	26.44	67.28	32.72
St-3	14.32	15.08	13.95	56.65	43.35	0.74	5.82	15.86	77.58	22.42	**0.03**	**0.03**	30.71	69.23	30.77
St-4	9.21	10.71	11.43	68.65	31.35	0.92	10.24	21.61	67.23	32.77	0.88	0.87	38.07	60.18	39.82
St-5	2.30	**1.30**	13.93	82.46	17.53	**0.39**	4.33	14.46	**80.82**	**19.18**	2.17	4.24	35.16	58.43	41.57
St-6	0.99	5.48	11.07	82.46	17.54	0.78	10.65	19.21	69.37	30.64	0.59	1.83	23.34	**74.24**	**25.76**
St-7	**14.63**	9.57	17.47	58.33	41.67	10.67	**28.59**	29.66	**31.07**	**68.92**	**9.24**	5.84	31.93	52.99	47.01
St-8	2.27	4.27	14.87	78.59	21.41	0.82	6.28	26.59	66.31	33.69	1.17	0.77	35.67	62.39	37.61
St-9	9.39	10.00	29.54	51.07	48.93	**15.77**	19.24	26.30	38.68	61.31	2.18	6.68	43.37	47.77	52.23
St-10	3.33	4.07	16.06	76.54	23.46	3.96	16.46	31.91	47.68	52.33	0.36	1.62	28.25	69.76	30.23
St-11	9.76	12.59	11.93	65.72	34.28	1.30	**3.13**	**35.57**	60.00	40.00	2.55	4.98	40.66	51.81	48.19
St-12	3.15	3.79	13.35	79.71	20.29	1.25	1.92	25.02	71.80	28.19	2.57	2.90	34.58	59.96	40.05
St-13	9.74	**23.65**	23.67	**42.94**	**57.06**	2.63	4.47	51.28	41.62	58.38	3.96	**7.24**	44.45	44.35	55.65
St-14	7.08	6.75	**8.43**	77.73	22.26	1.57	5.68	29.46	63.29	36.71	3.76	1.22	31.30	63.72	36.28
St-15	4.17	9.46	**30.47**	55.91	44.10	4.46	22.94	34.00	38.60	61.40	0.81	1.37	30.90	66.91	33.08
St-16	9.63	4.33	1.22	**84.82**	**15.18**	1.02	9.57	17.74	71.67	28.33	1.35	1.37	27.44	69.84	30.16
St-17	2.65	2.71	15.96	78.68	21.32	7.86	11.12	23.47	57.54	42.45	1.95	3.04	40.49	54.52	45.48
St-18	**0.58**	1.53	14.36	83.53	16.47	13.46	14.76	20.03	51.75	48.25	3.59	4.27	52.65	39.48	60.51
St-19	6.28	3.07	13.67	76.98	23.02	8.22	19.11	27.88	44.79	55.21	0.67	2.19	54.72	42.43	57.58
St-20	3.44	5.09	21.80	69.67	30.33	9.58	10.20	**13.60**	66.62	33.38	2.04	3.27	**56.20**	**38.50**	**61.51**

Note: Values in bold indicate minimum or maximum concentrations for each fraction. F1 = EFLE

1.30-23.65% in the acid-reducible fraction, 8.43-30.47% in the oxidisable-organic fraction and 42.94-84.82% in the resistant fraction.

Meanwhile, 19.18 to 68.92% of non-resistant Zn fraction was shown. In these non-resistant Zn fractions, Zn is highly associated with the oxidisable-organic fraction, accounting for 13.60-35.57% of the total Zn. Generally, the 'oxidisable-organic' fraction contributed the largest percentage of metals among the other three anthropogenic-related fractions which had been reported for intertidal and drainage sediments of Selangor (Yap *et al.*, 2008b). In particular, Zn was partitioned at 0.39-15.77% in the EFLE fraction, 3.13-28.59% in the acid-reducible fraction, and 31.07-80.82% in the resistant fraction. The Ni in the sediments is also strongly associated with the resistant fraction (38.50-74.24) and slightly bound to EFLE (0.03-9.24%), while acid-reducible phase accounts for 0.03-7.24% and oxidisable-organic fraction accounts for about 22.75-56.20% of Zn in the sediments. Meanwhile, Zn in the non-resistant fraction was found to be 25.76-61.51%. The present results on Cd and Zn are within the range reported by Yap *et al.* (2008b: 2008c) for the drainage sediment from the industrial area in Selangor.

Based on the data presented in Table 7, it was found that almost 50% (48.9%) of the total Cd concentrations were contributed by non-resistant fraction at St-9, which recorded the highest total Cd concentration. However, the highest percentage (57.1%) of Cd non-resistant was found at Sg. Berembang (St-13) although it had 1.38 µg/g dw of the total Cd concentration. This might indicate the fact that the majority (>50%) of the total Cd was contributed by anthropogenic origins. The percentages of the non-resistant fractions for Zn could also be clearly contributed by anthropogenic sources at St-9 (61.3%) and St-19 (55.2%), while the total Ni concentrations at St-9, St-18, St-19, and St-20 were mostly (>50%) contributed by anthropogenic sources. An increase in the relative importance of the non-resistant fraction was associated with contaminated conditions and this has been well documented in the literature (Ismail and Ramli, 1997; Ismail *et al.*, 2004; Yap *et al.*, 2007: 2008a, b, c). A higher percentage (>50%) of the non-resistant fraction of metals indicates the anthropogenic sources of these metals for Sepang River (Yap *et al.*, 2007a) and drainage sediments in Selangor (Yap *et al*., 2008b, c) and Sri Serdang Industrial Area (Yap *et al.*, 2009). These non-resistant metal percentages indicated that the metal concentrations were dominated by the anthropogenic sources since the non-resistant fraction of metals was mostly contributed by the anthropogenic sources (Badri and Aston, 1983; Yap *et al.*, 2002).

CONCLUSIONS

The wider ranges of Zn and Ni concentrations for the sediment collected from the north western intertidal area of Peninsular Malaysia were found when compared to the previously reported studies. The geochemical study revealed that the same sampling sites (namely Kuala Kurau town and 3 sites at Juru River basin) were clustered together, indicating a high contaminations of Cd, Zn, and Ni. The higher percentages of non-resistant fractions gathered in this study based on geochemical fractions also indicated the anthropogenic sources in the northwestern part of Peninsular Malaysia. Although this paper is just another monitoring work reporting the same phenomenon as those by Yap *et al.* (2002) and Yap *et al.* (2003), monitoring of the intertidal environment in the current study should be conducted on a regular basis. As ecotoxicologist who is concerned with the fate of the environment, the present data should provide a continued effort for future reference. Meanwhile, the elevated concentrations of Cd, Zn, and Ni that were found in some sampling sites should prompt proper actions, as well as better management and control to enhance environmentally sustainable development in Malaysia.

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